

BRAHMS

Annual RHIC DOE Science and Technology Review
July 6-8, 2005

F.Videbaek
Spokesperson
Physics Department
BNL



Overview

- Science and priorities
 - How has BRAHMS addressed the science priorities of RHIC
- Accomplishments
 - Recent results
 - Scientific output
 - RHIC run-4/5 upgrades, performance
- Plans
 - Expected results from ongoing analysis
 - Future RHIC runs
- Issues
 - RHIC user and experiment interfaces (collaboration perspective)

RHIC Science Questions

Outstanding questions about strongly interacting matter:

“How does matter behave at very high temperature and/or density?”

- Jet-quenching suppression in AA, not d-A
- Au-Au, Cu-Cu, pp. Bulk properties energy dependence

“What is the nature of gluonic matter? and how does it appear inside of strongly interacting particles?”

- d Au at high rapidities (low-x)

“What is the spin structure of the nucleon ?”

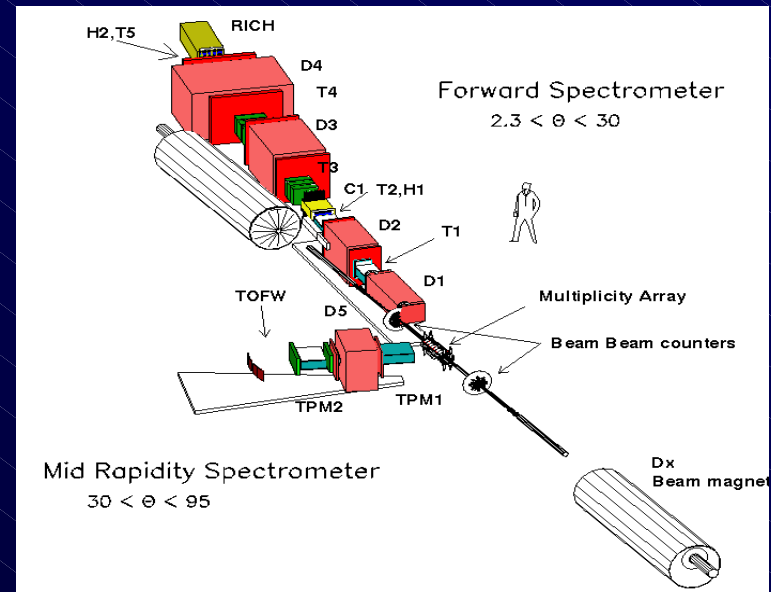
- Single Spin Asymmetries at large x_F

BRAHMS Experiment and Goals

Physics questions that are being addressed

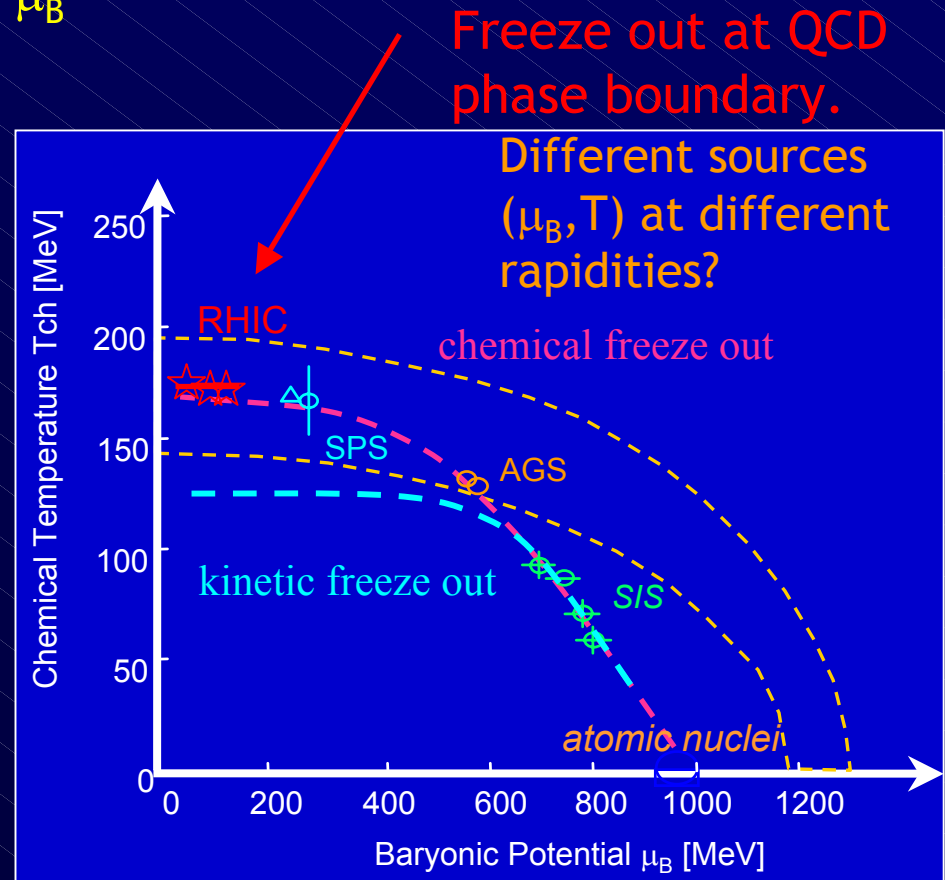
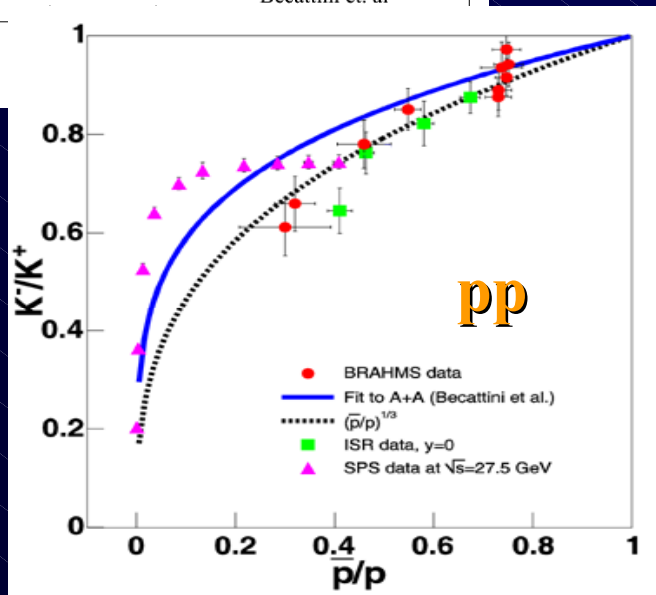
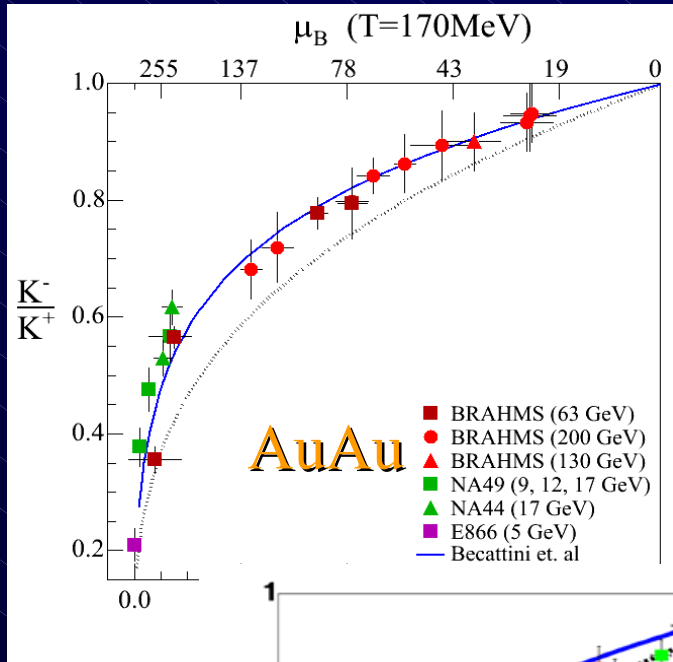
- How much energy is available for particle production ?
- How do particles flow in the transverse & longitudinal direction?
- What is the chemistry of the system?
- What is the rapidity dependence of jet quenching ?
- What can we learn about the parton distributions in the Au nuclei at small x ?
- What is internal angular momentum in proton?

- The experiment has unique capabilities in terms of precision measurements and particle ID covering a rapidity range of 0-4 and up to moderate high p_t (~ 4 GeV/c)



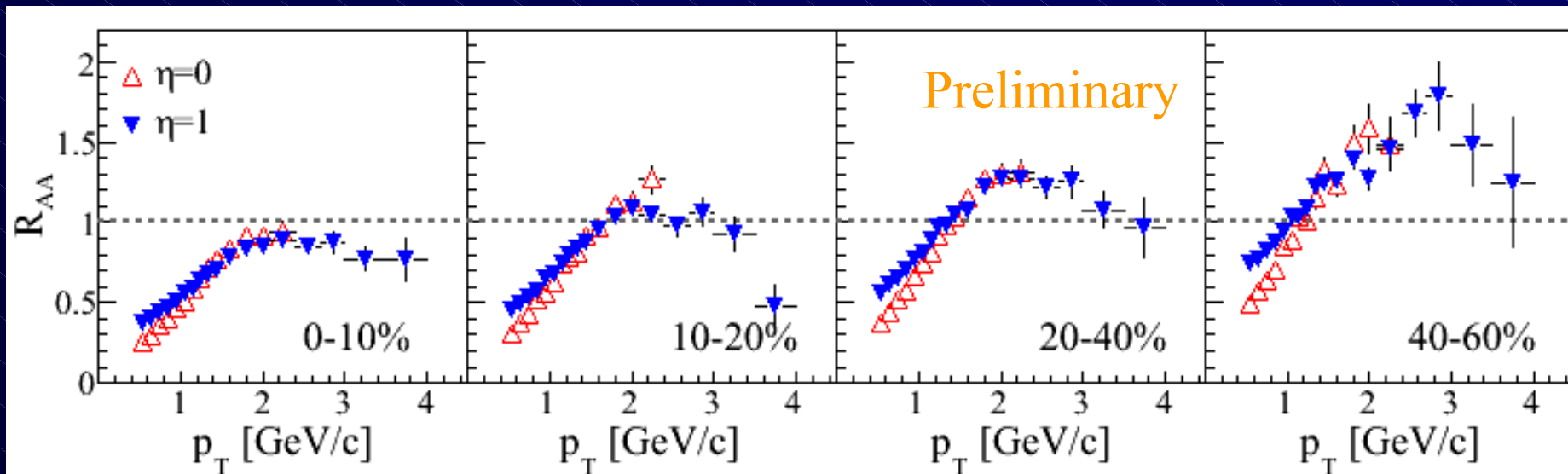
Ratios - Chemical freeze out

Hadron Gas Statistical model
(grand canonical ensemble)
reproduces (all) particle ratios
 $\Rightarrow T_{\text{ch}}, \mu_B$



Centrality dependence of high- p_T suppression

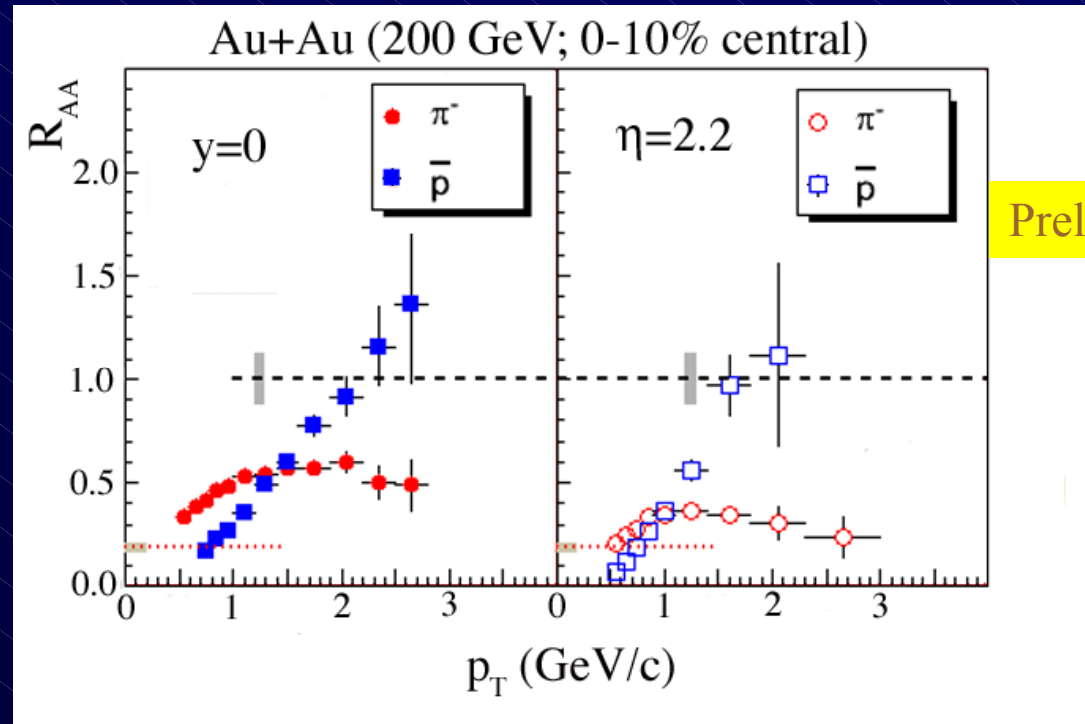
RAA(62.4 GeV Au+Au)



Suppression is observed at 62 GeV
RAA values overall smaller than at 200
Reference spectrum is poorly known

Rapidity dependence of Suppression.

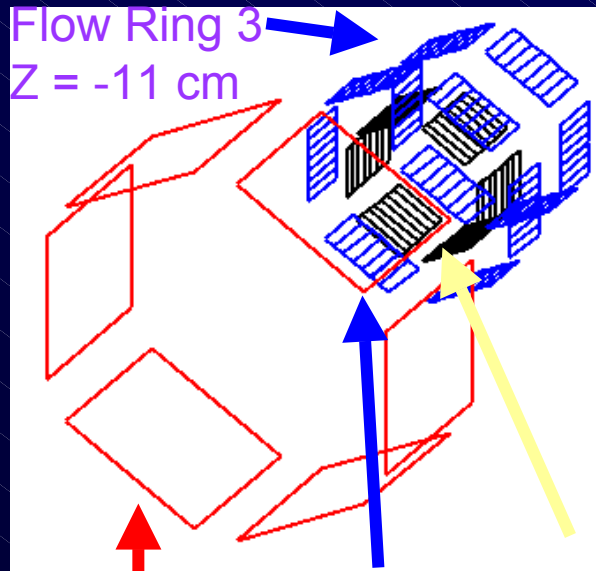
R_{AA} vs.
•rapidity
•flavor



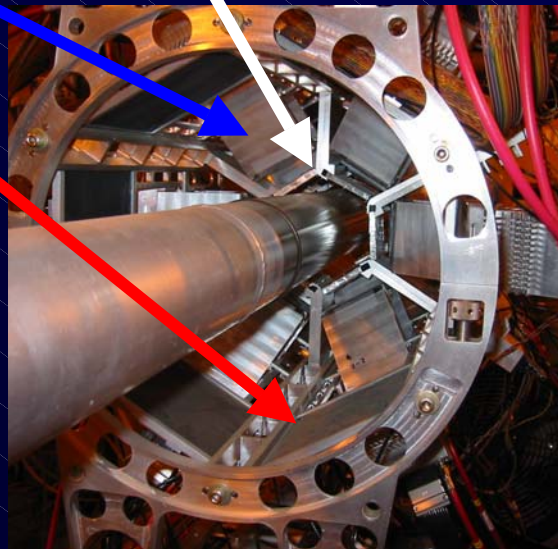
Preliminary

R_{AA} depends on energy-loss, density and underlying reference spectrum

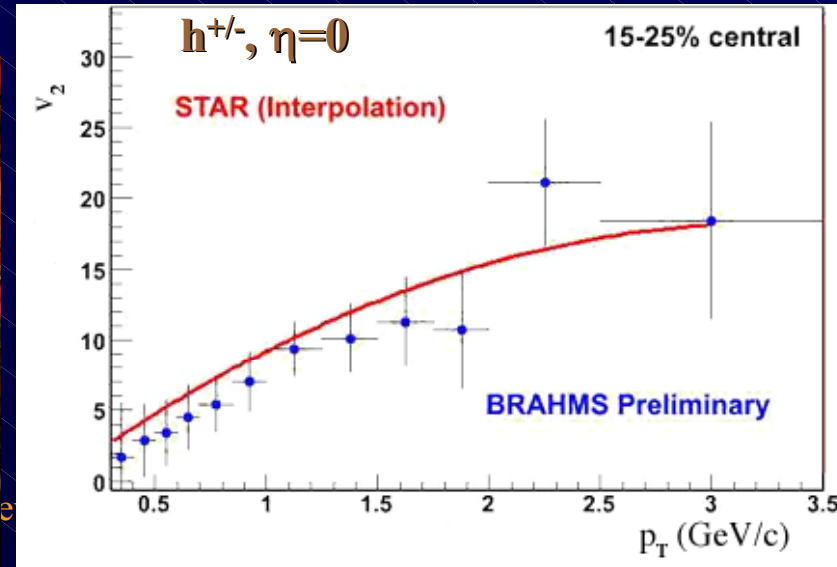
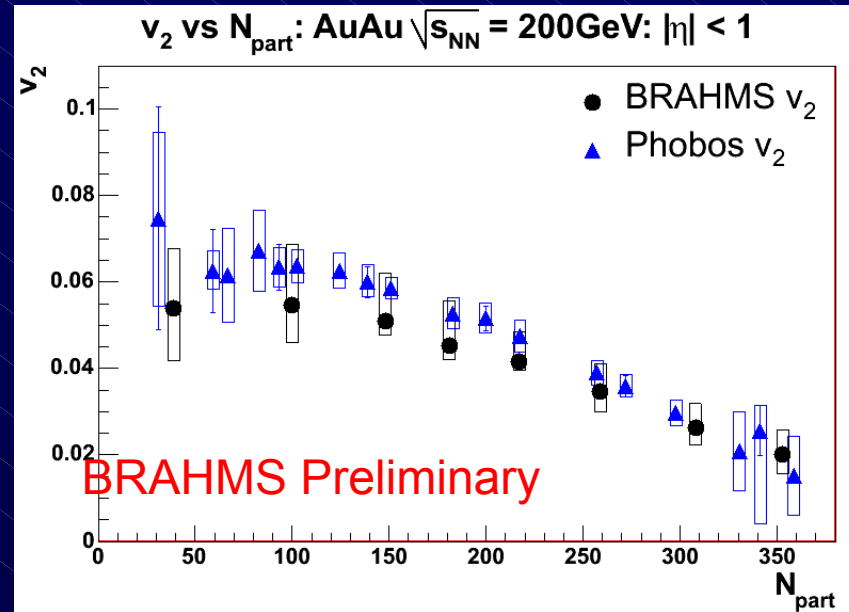
Elliptic flow in BRAHMS



Tile Ring 1
Flow Ring 2
Si Ring 1



Identified particle
 $v_2(p_T)$ over an
extended η range,
 $0 < \eta < 3.2$, will be
presented at
QM2005...



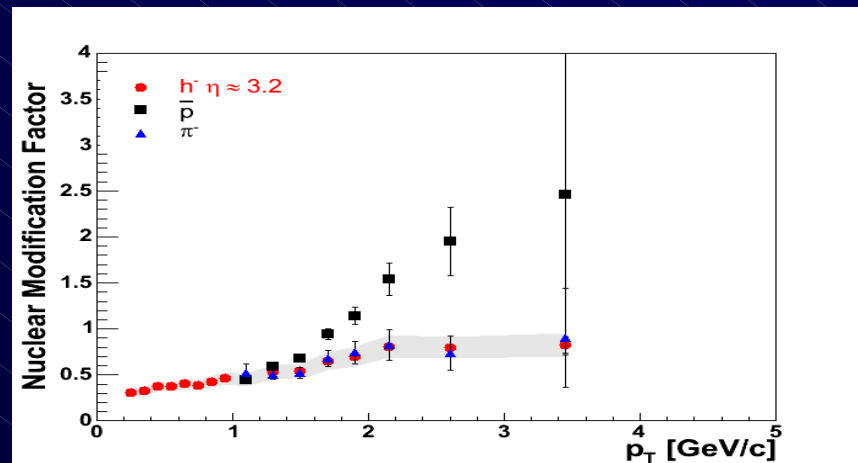
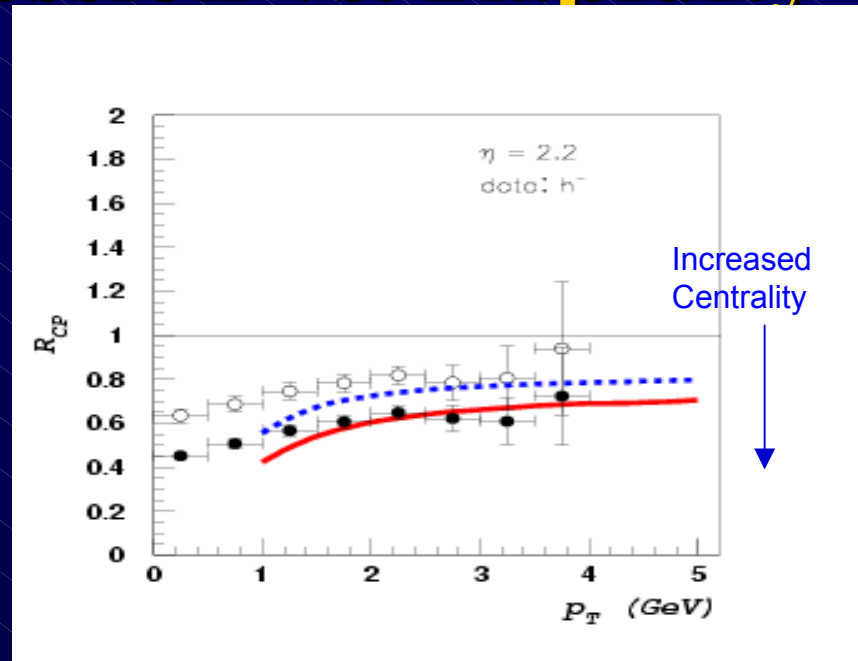
Nuclear Suppression vs. Rapidity

Motivation for measurements at large rapidity in d-Au collisions comes from the investigation of CGC.
(initial vs final state effects)

- BRAHMS data analyzed by Kharzeev, Kovchegov and Tuchin using the CGC as underlying description for a quantitative analysis.

Interpret as coherence that becomes more important with increasing energy and low-x.

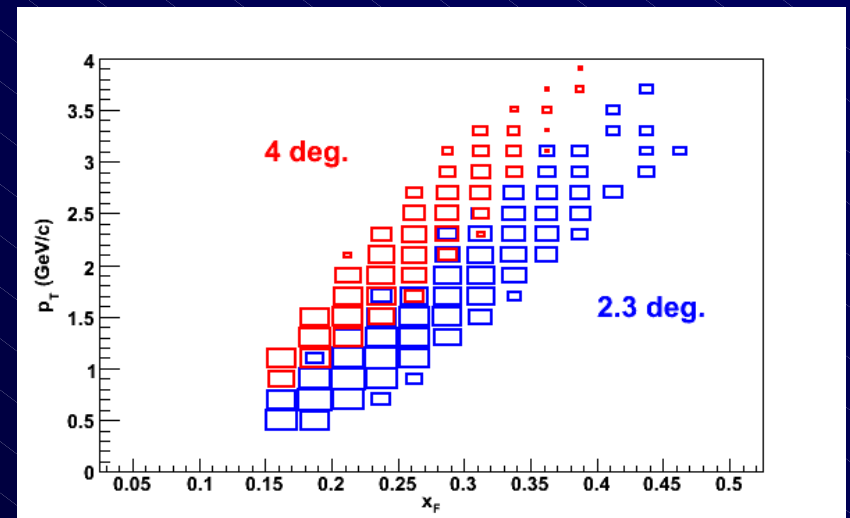
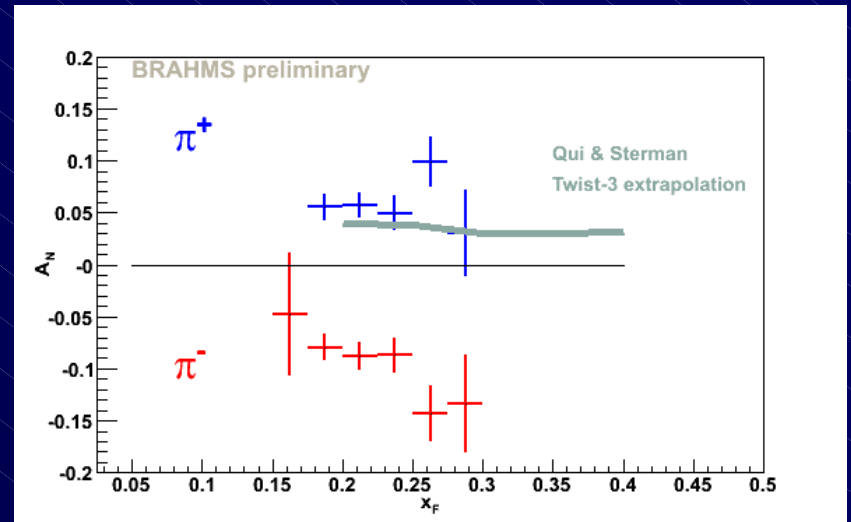
Investigating for identified hadrons.
Strong suppression for π^- .
Enhancement for p-bar



RHIC Spin

What is the role of transverse spin in QCD?

- Transverse Spin measurements can be made at forward region.
- BRAHMS has obtained the first preliminary result for single spin asymmetries for π^+ and π^- in 200 GeV pp collisions at RHIC in the x_F range of 0.17 to 0.32
- The A_N value for π^+ and π^- are significantly different with opposite sign, and the $\pi^- < 0$ at ~ 3 sigma level and $\pi^+ > 0$ at ~ 1.5 sigma level
- The data from run-5 will allow exploration of pt-dependence



Publications

2000-2005 **12** Refereed Journals

2000-2005 **45** Conference proceedings

2000-2005 **90+** Talks at conferences , meetings and workshops

- *Recent Publications*
- "Centrality Dependent Particle Production at $y=0$ and $y \sim 1$ in Au+Au Collisions at $\sqrt{s_{NN}} = 200$ GeV" **Accepted to Phys. Rev. C in 6/3/2005**
- "Charged Meson Rapidity Distributions in Central Au+Au Collisions at $\sqrt{s_{NN}} = 200$ GeV" **Phys. Rev. Lett. 94, 162301 (2005)** , [nucl-ex/0403050](#)
- "Forward and Midrapidity Like-particle Ratios from p+p Collisions at $\sqrt{s_{NN}}=200$ GeV" **Phys. Lett. B607, 42-50 (2005)**
- "Centrality Dependence of Charged-particle Pseudorapidity Distributions from d+Au Collisions at $\sqrt{s_{NN}}=200$ GeV" **Phys. Rev. Lett. 94, 032301 (2005)** , [nucl-ex/0401025](#)
- "Quark-gluon plasma and the color glass condensate at RHIC? The perspective from the BRAHMS experiment" **Nucl. Phys. A757 (2005) 1-27**, [nucl-ex/0410020](#)
- "Evolution of the Nuclear Modification Factors with Rapidity and Centrality in d+Au Collisions at $\sqrt{s_{NN}}=200$ GeV" **Phys. Rev. Lett. 93, 242303 (2004)** , [nucl-ex/0403005](#)

Citations

- 4 top citations from BRAHMS
 - (124) TRANSVERSE MOMENTUM SPECTRA IN AU+AU AND D+AU COLLISIONS AT $S^{1/2} = 200$ -GEV AND THE PSEUDORAPIDITY DEPENDENCE OF HIGH P(T) SUPPRESSION.
Published in *Phys.Rev.Lett.*91:072305,2003
 - (73) ON THE EVOLUTION OF THE NUCLEAR MODIFICATION FACTORS WITH RAPIDITY AND CENTRALITY IN D + AU COLLISIONS AT $S(NN)^{1/2} = 200$ -GEV.
Published in *Phys.Rev.Lett.*93:242303,2004
 - (73) PSEUDORAPIDITY DISTRIBUTIONS OF CHARGED PARTICLES FROM AU+AU COLLISIONS AT THE MAXIMUM RHIC ENERGY.
Published in *Phys.Rev.Lett.*88:202301,2002
 - (71) PSEUDORAPIDITY DISTRIBUTIONS OF CHARGED PARTICLES FROM AU+AU COLLISIONS AT THE MAXIMUM RHIC ENERGY.
Published in *Phys.Rev.Lett.*88:202301,2002

Publications in Preparation

- R_{AA} for identified hadrons at $\eta \sim 0$ and $\eta \sim 2$
- High-pt suppression in Au-Au at 62 GeV
- Particle production for identified particle vs. rapidity at 62 GeV Au-Au reactions
- Single Spin Asymmetries for π^\pm at 200 GeV pp

Collaboration

Educational Output

11 Institutions in 5 Countries.

36 Scientists, 5 Post Docs, 8 Ph.D students, 4 MS students

year	Ph.D thesis
2005	2
2004	2
2003	2
2002	1
..2001	2

In addition ~15 M.S. thesis

FY04/05 Exp. Improvements

- Infrastructure (C-AD)
 - Shielding from Tunnel Background
 - Extend walkover
 - Operations support
 - Magnets, power supplies,...
 - Survey
 - Electronic (HEEP)
- Experiment
 - CC--Beam normalization and vertex
 - VME Trigger Electronics for spectrometer triggers
 - Upgrade of Online computing and Database
 - Shower Max detector for ZDC

Run-5 Data Taking

DAQ time for Jan. 16– Mar. 8: 430 hours ~9 hours/day

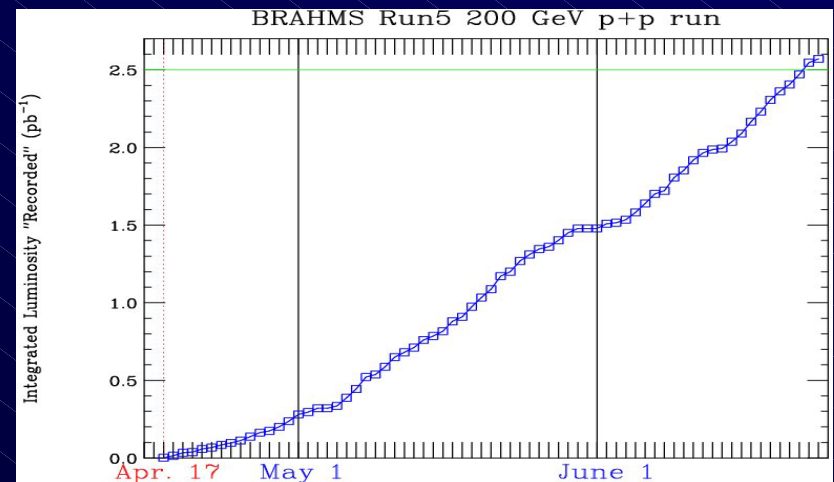
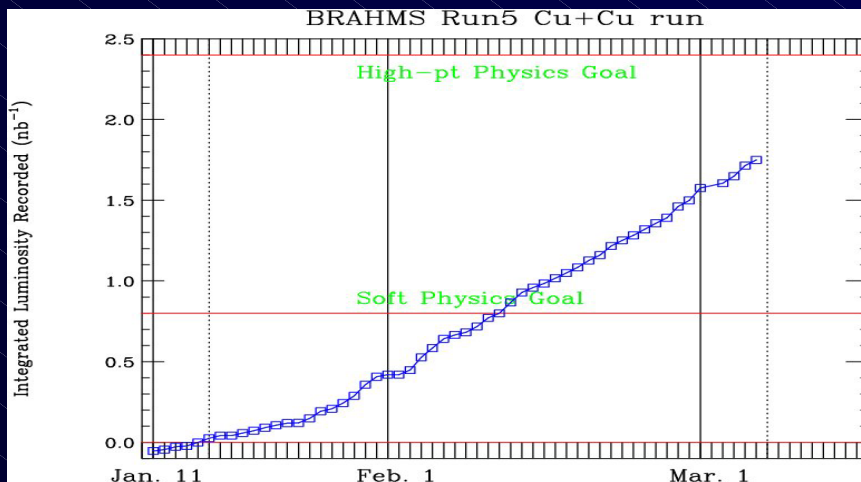
Data Summary

- ~1.75 nb-1 Cu+Cu 200 GeV recorded
- All of soft Physics Goal Achieved.

Data Summary 62.4 GeV

- Total 120mb-1 Recorded
- Achieved the luminosity goal for physics

~2.57 pb-1 recorded (April 17th – June 24th)
Exceeded Physics goal from Beam Use Proposal.



Analysis Status

- Baseline Measurements are essentially completed with the extended high luminosity runs of Au-Au , Cu-Cu and pp at 200 and 62.4 GeV
- The focus has been on unique forward coverage
 - Transverse spectra of π , K, p
 - Elliptic Flow
 - Small-x physics
 - Transverse flow
 - Suppression of high Pt particles
 - Transverse spin measurements at $x_f=0.2$ to 0.4
- Analysis and publication of data will take ~ 2 additional years (based on experience with similar size experiments)
- This matches the time-scale for several students and post docs, and involvement of European groups that go to ALICE

Analysis priorities

- AuAu 62 and 200 GeV
 - Flow analysis
 - Rapidity and centrality dependence of pt-suppression
 - Rapidity and centrality dependence of soft physics
 - Data production have been completed. All at analysis stage
- CuCu 62 and 200 GeV
 - Comparison of particle production and pt dependence at 62 GeV and 200 GeV
 - Comparison of jet-quenching via R_{cp} and RAA to AuAu
- Pp at 200 GeV
 - Spin Asymmetries A_N (bulk of data)
 - High statistics reference spectra at large η . Flavor dependence of fragmentation

Considerations for Future

The polarized spin program is most likely completed with this year's extensive run. Will know as analysis is progressing

Additional running is being considered by the Collaboration

The low-x measurements in d.Au collisions can be dramatically improved by a modest investment of resources

This would address in greater detail the R_{dA} p_T and specie dependence, and can clarify importance of initial states vs. final state effects

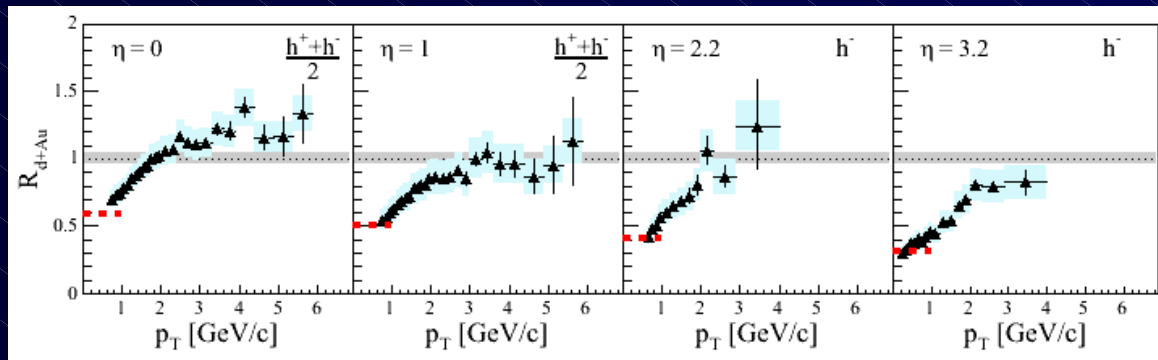
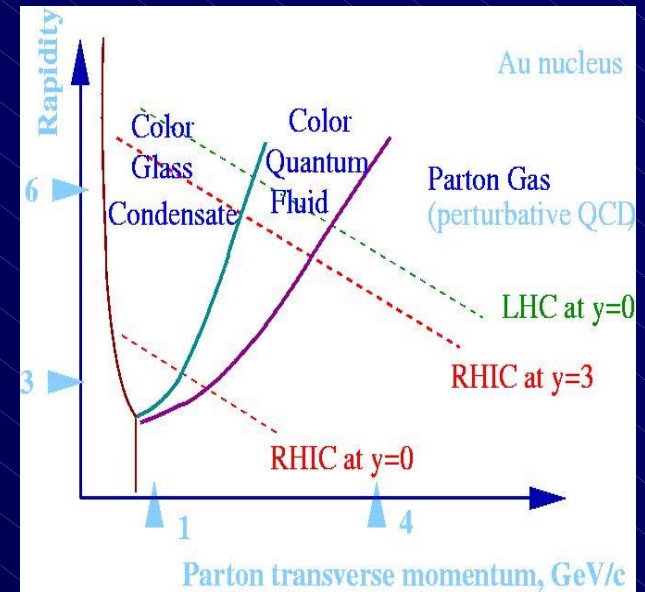
One ALICE PHOS module might be brought to RHIC. Could result in π^0 or direct gamma measurements at forward or backward rapidities in dA (AA) collisions

Low-x physics

Motivation for measurements at large rapidity in d-Au collisions comes from the investigation of CGC.

High precision measurements may be able to further clarify the importance of gluon saturation,

Pursue the physics of understanding initial vs. final state effects. In-medium fragmentations and projectile energy loss.



Probing low and high x in Nuclei

Extend p_T reach to ~ 5 GeV/c for inclusive charged hadron spectra

With luminosities projected by CA-D for FY07 one can extend reach to ~ 5 GeV/c in a 8-10 week run

Would allow precision study of centrality and meson-baryon dependence

Highly desirable to extend precision measurements to backward rapidities

Make as few modifications to existing experiment as possible, to enhance science output from another run

PHOS@BRAHMS

- The ALICE PHOS group has expressed interest in making physics measurements at RHIC with one 3,500 crystal super module.
- BRAHMS' open geometry allows to place the PHOS module at various distances from the interaction region and at pseudo rapidities between $\eta=0$ and $\eta=3$
- Physics program
 - High-pt π^0 and η production at forward or backward rapidities in d+Au or nucleus-nucleus collisions
 - Direct photon HBT correlations
- The timescale for RHIC running, the construction completion of one PHOS element and subsequent return to ALICE that make this difficult, but is still being explored

Planning for this Direction

- Preparation of LOI for BNL for presentation at PAC
- Evaluate modifications needed to optimize and enhance the program while utilizing as much as possible of the existing spectrometer
- Seek additional manpower for such dedicated experiment
- The backward rapidities measurements might be easiest achieved by a spectrometer there rather than having beams reversed

Timeline

- FY06 (summer) Modification of detector system
- FY07 running
 - The effort is contingent on (some) assurance that a run 7 would be a dA run. Several interested parties have commitments in out-years
- FY08 analysis of data.

Not intended to be a long term effort, but a concerted effort to greatly improve the experimental basis for low-x physics at RHIC and its implication for the CGC interpretation

Interaction with BNL Facilities

- RHIC computing (RCF)
 - Resources have met or exceed the requirements for BRAHMS
 - The support of the personnel has good
 - HPSS has been crucial in storing and booking the BRAHMS raw and reconstructed data. HPSS does at times exhibit failure modes, disrupting the first tracking pass of the reconstruction, requiring additional attention and delays in production
- C-AD
 - The support from C-AD to the experiment has been outstanding
- RHIC/AGS Users' Center
 - Help with visa, approval, safety training and general issues most valuable for experimenters

Conclusions

- BRAHMS has performed an extensive survey of identified hadron production with its unique y - p_t coverage in Heavy Ion reactions at RHIC
- The flexibility of the experiment and RHIC facility allowed for unique measurements in d-Au and spurred extensive interest in low- x physics at RHIC and LHC
- BRAHMS has contributed with significant and unique measurements for the RHIC spin program
- There is an opportunity to make additional unique set of compelling measurements at large rapidity in d-Au system, that could be done in the timeframe of RHIC run-7